Endosaccular Treatment of Intracranial Aneurysms Using Matrix Coils
Early Experience and Midterm Follow-Up

Yasunari Niimi, MD, PhD; Joon Song, MD; Mary Madrid, RN, PhD; Alejandro Berenstein, MD

Background and Purpose—The authors report their experience using Matrix coils in the treatment of cerebral aneurysms.

Methods—The outcomes of 72 consecutive patients (76 aneurysms) who underwent coiling using Matrix coils at our institution were retrospectively analyzed.

Results—Seventy-four aneurysms in 70 patients were coiled using Matrix coils (ranging 3% to 100% by coil length; mean 68.8%). Two patients underwent regular platinum coil embolization after failed Matrix coil placement. Thirty-two (42%) ruptured aneurysms were acutely treated. In 46 aneurysms, Matrix composed >50% of coil length. Complete aneurysm occlusion was obtained in 13 aneurysms (17.6%), neck remnant in 30 (40.5%), and dome filling in 31 (41.9%). Procedural morbidity and mortality rates were 1.4% and 1.4%, respectively. Angiographic follow-up was obtained in 63.5% (47 of 74 aneurysms; average 12.2 months; range 0 to 34). In these 47 angiographically followed aneurysms, the overall recanalization rate was 57.4%. In aneurysms with >50% Matrix coils, 76.1% had angiographic follow-up (35 of 46), and in this group, the overall recanalization rate was 54.3% (19 of 35): 25% (1 of 4) for very small (<5 mm); 33% (4 of 12) for small-size (<10 mm)/small-neck (<4 mm); and 63% (5 of 8) for small-size/wide-neck (≥4 mm). A total of 82% (9 of 11) recanalization occurred in large aneurysms (≥10 to 25 mm). Ten aneurysms (21.3%; 10 of 47) underwent retreatment. Clinical follow-up was obtained in 61 (86%) patients (average 15 months; range 1 to 37): 87% of patients were Glasgow Outcome Scale 4 or 5.

Conclusion—The use of Matrix coils resulted in worse recanalization rates than that reported for Guglielmi detachable bare platinum coils. (Stroke. 2006;37:1028-1032.)

Key Words: cerebral aneurysm ■ embolization ■ therapeutic

Endovascular coiling of intracranial aneurysms has been progressively more accepted worldwide.1,2 However, recanalization attributable to coil compaction remains the major limitation of coiling, particularly wide-necked or larger aneurysms.3–6 When aneurysms are not completely occluded, the risk of coil compaction and aneurysm recanalization is significant.4 Multiple attempts have been made to modify coils to reduce recanalization. Bioactive coils are designed to enhance organization of thrombus surrounding the coils.7 The Matrix coil (Boston Scientific Inc.) was the first bioactive coil to become commercially available (2002). The Matrix coil is composed of a platinum core (30% volume) coated with a polyglycolic acid and polyglycolic/poly-L-lactic acid copolymer (70% volume).7,8 This coil was tested on experimental side-wall aneurysms before its clinical introduction. However, controversy exists about the clinical efficacy of Matrix, with only a few published clinical studies.9–13 We began using Matrix coils in June 2002 at our institution as 1 of 11 international (5 in the United States) institutions selected for the premarket clinical study (ACTIVE study14). We present our single center experience using the Matrix coil, including midterm follow-up results.

Material and Methods

Patient Selection

Between June 2002 and January 2005, Matrix coils were used in the treatment of 76 cerebral aneurysms in 72 patients. There were no strict inclusion criteria. Endosaccular coiling of an aneurysm was performed when it was considered the best treatment option after prospective evaluation by both endovascular surgery and vascular microsurgery teams or when the patient refused surgery. Nine aneurysms in 8 patients were treated predominantly with Matrix coils to register in the premarket clinical study (ACTIVE study14). For the rest, other coils were used in combination with Matrix coils based on operator preference. Two aneurysms were treated with only bare platinum coils after failed Matrix attempt. The anatomic and clinical outcomes of the rest of 70 patients with 74 Matrix-treated cerebral saccular aneurysms were retrospectively studied.

There were 15 males and 55 females. Aneurysm location was in the anterior circulation in 59 and in the posterior circulation in 15 cases. Forty-three aneurysms were unruptured or in the chronic

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phase of hemorrhage, and 31 aneurysms were in the acute phase (Hunt\&Hess grade 1 to 4). Vasospasm was present in 5 cases. Seventeen aneurysms were treated previously: 13 by coiling, 3 by clipping, and 1 by both clipping and coiling. Three large (L) aneurysms and 1 giant (G) aneurysm contained thrombus. Aneurysms were divided into 5 categories: 5 very small (<5 mm) narrow-necked (VS/S), small (5 to 10 mm) narrow-necked (S/S; <4 mm), small wide-necked (S/W; ≥4 mm), large (L; ≥10 to 25 mm), and G (≥25 mm) aneurysms (see Table 1).

### Endovascular Treatment

The technique for endovascular coil treatment has been described previously.5,15 Almost all procedures were performed on a biplane angiographic system (Siemens) with 3D-rotational digital subtraction angiography. Almost all cases were performed under general anesthesia and with systemic anticoagulation. In most cases, intravenous heparin was continued for 24 to 48 hours. Balloon-remodeling technique was used in 12 (16.2%) procedures.16 Stent-assisted coiling was performed in 4 (5.4%) procedures.17,18

### Complication Assessment

Procedure-related morbidity was recorded as permanent new neurological deficit after embolization. Procedure-related death was recorded as death directly related to procedure such as intraoperative rupture or procedure-related ischemic stroke. Delayed rehemorrhage was not included in procedure-related mortality but was recorded. Clinical follow-up data were collected by review of hospital charts, evaluation at last clinic visitation or follow-up angiography, or by telephone interview. Patients’ neurological outcome ≥1 month after the treatment was recorded using both Glasgow Outcome Scale (GOS) and modified Rankin Score (mRS).

### Angiographic Evaluation

Angiographic results were recorded immediately after treatment and on follow-up. The classification of angiographic results as defined by Roy et al19 was also recorded immediately and on follow-up: class 1, complete occlusion; class 2, persistence of any portion of the original defect of the arterial wall as seen on any single projection but without opacification of the aneurysm sac; and class 3 aneurysm sac opacification.

### Angiographic Follow-Up Strategy and Evaluation

For all treated aneurysm patients, follow-up skull x-ray films were requested at 3 months. If skull X-ray films showed evidence of coil compaction, angiography was recommended immediately. Otherwise, for ruptured aneurysm patients, a 6-month follow-up angiogram was recommended. For unrepaired aneurysm patients, a 1-year follow-up angiogram was recommended. Angiograms were also recommended at 3-year and at 5-year follow-up.

Any increase in contrast filling on the multiple views of follow-up angiogram was considered recanalization. In addition, to better compare recanalization results with Oguliehmi detachable coil (GDC) bare platinum coils, the same definition of recanalization was used as that defined in the 11-year University of California at Los Angeles (UCLA) experience:10 recanalization was defined as >10% increase in contrast filling of the aneurysm; <10% increased filling was defined as unchanged.

### Results

#### Clinical Outcome

Procedure-related morbidity and mortality was 1.4% each. One patient underwent endovascular coiling of the 2.7-mm postsubarachnoid residual aneurysm using 40% Matrix coils by length. During the coiling procedure, clot formation in the A2 segment of the anterior cerebral artery was noted. This was treated with intraarterial Reopro injection with resolution of the clot. Postprocedure computed tomography scan showed evidence of extravasation. The patient remained neurologically unchanged immediately after the procedure but died in the nursing home within 1 month of the treatment. Thromboembolism occurred in 4 procedures (5.4%), causing 1 permanent neurological deficit (1.4% morbidity). Coil protrusion to the parent artery occurred in 4 cases, causing 2 thromboemboli. One protruded coil was tacked against the vessel wall by placing a Neuroform stent without clinical sequela. Asymptomatic occlusion of the ophthalmic artery origin occurred in 1 case of a coiled ophthalmic aneurysm. There were 2 other asymptomatic technical complications. In 1 case, during an attempt to pull back a partially placed Matrix, another previously detached Matrix coil was entangled with this coil and came back together into the microcatheter. Both coils were successfully removed by removing the microcatheter and coils together. In another case, a Matrix coil formed a knot, which was successfully undone.

Clinical follow-up was obtained in 62 patients ranging from 1 month to 37 months, with an average of 15 months. Follow-up GOS was 5 in 43, 4 in 10, 3 in 3, 2 in 2, and 1 in 3 patients. Follow-up mRS was 0 in 39, 1 in 4, 2 in 7, 3 in 4, 4 in 2, 5 in 2, and 6 in 3 patients. One 3-month-old infant could not be evaluated by GOS or mRS. One patient experienced delayed rehemorrhage but survived.

### Immediate Angiographic Outcome

Immediate postprocedure angiography demonstrated overall class 1 complete aneurysm occlusion in 17.6% (13 of 74), class 2 neck remnant in 40.5% (30 of 74), and class 3 incomplete occlusion in 41.9% (31 of 74). Table 1 summarizes class 1, 2, and 3 angiographic results for VS/S, S/S, S/W, L, and G aneurysms. Near total or total occlusion of the aneurysm (class 1 or 2) was obtained in 65% of <10-mm aneurysms with a small neck (VS/S and S/S), in contrast to 48% of S/W aneurysms or L aneurysms (S/W, L, and G). On average, Matrix coils comprised 68.8% (ranging 3% to

### Table 1. Immediate Angiographic Results

<table>
<thead>
<tr>
<th></th>
<th>VS/S</th>
<th>S/S</th>
<th>S/W</th>
<th>L</th>
<th>G</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>2 (1)</td>
<td>2 (1)</td>
<td>3 (2)</td>
<td>2 (2)</td>
<td>3 (3)</td>
<td>0</td>
</tr>
<tr>
<td>Class 2</td>
<td>2 (2)</td>
<td>12 (9)</td>
<td>2 (2)</td>
<td>5 (3)</td>
<td>1 (0)</td>
<td>22 (16)</td>
</tr>
<tr>
<td>Class 3</td>
<td>1 (1)</td>
<td>2 (1)</td>
<td>5 (4)</td>
<td>7 (5)</td>
<td>0</td>
<td>15 (11)</td>
</tr>
<tr>
<td>Total</td>
<td>5 (4)</td>
<td>17 (12)</td>
<td>9 (8)</td>
<td>15 (11)</td>
<td>1 (0)</td>
<td>47 (35)</td>
</tr>
</tbody>
</table>

Numbers in the parentheses indicate numbers of aneurysms treated with >50% Matrix coils by length.

### Table 2. Size and Immediate Angiographic Results of Aneurysms With Angiographic Follow-Up

<table>
<thead>
<tr>
<th></th>
<th>VS/S</th>
<th>S/S</th>
<th>S/W</th>
<th>L</th>
<th>G</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>2 (1)</td>
<td>2 (1)</td>
<td>3 (2)</td>
<td>3 (3)</td>
<td>0</td>
<td>10 (8)</td>
</tr>
<tr>
<td>Class 2</td>
<td>2 (2)</td>
<td>12 (9)</td>
<td>2 (2)</td>
<td>5 (3)</td>
<td>1 (0)</td>
<td>22 (16)</td>
</tr>
<tr>
<td>Class 3</td>
<td>1 (1)</td>
<td>2 (1)</td>
<td>5 (4)</td>
<td>7 (5)</td>
<td>0</td>
<td>15 (11)</td>
</tr>
<tr>
<td>Total</td>
<td>5 (4)</td>
<td>17 (12)</td>
<td>9 (8)</td>
<td>15 (11)</td>
<td>1 (0)</td>
<td>47 (35)</td>
</tr>
</tbody>
</table>

Numbers in the parentheses indicate numbers of aneurysms treated with >50% Matrix coils by length.
Follow-Up Angiographic Outcome

Follow-up angiographic results were obtained in 44 patients with 47 Matrix coil–treated aneurysms (63.5%). Among 46 aneurysms treated with >50% Matrix coils, 35 (76.1%) had follow-up angiography. Table 2 lists the sizes and immediate angiographic occlusion after treatment of these angiographically followed aneurysms. Angiographic follow-up was obtained from 4 days to 34 months, with an average of 12.0 months. Among them, 3 aneurysms in 3 patients had >2-month angiographic follow-up, of which 1 aneurysm showed early coil compaction and recanalization. In this follow-up group, the percentage by length of Matrix coils was 67.5% for the total group and 81.1% for 35 aneurysms treated with >50% Matrix coils.

Comparison of occlusion class immediately after treatment and at last follow-up showed that 17.0% of aneurysms had improved, 55.3% were stable, and 27.7% had worse class (Table 3). These numbers did not significantly differ for the aneurysms treated with >50% Matrix coils. Worsened cases occurred in 0% of VS/S, 29.4% of S/S, 22.2% of S/W, and 33.3% of L aneurysms. One G aneurysm worsened.

Aneurysm Recanalization

In 47 angiographically followed aneurysms, the overall recanalization rate was 57.4%. Based on recanalization defined as >10% increase in opacified aneurysm, the recanalization rate was 40.4% (Table 4). These numbers were 54.2% and 42.9%, respectively, for the 35 aneurysms with >50% Matrix (Table 5). Recanalization rate of L aneurysms treated with >50% Matrix was 81.8%.

There were 14 aneurysms retreated with Matrix coils because of recanalization after coiling with bare platinum coils. Among them, 11 aneurysms underwent follow-up angiogram, of which 9 (81.8%) had >10% recanalization on follow-up angiography.

Twelve aneurysms underwent >1 angiographic follow-up with the first follow-up angiogram >3 months after treatment. Among those 12 aneurysms, 2 showed new recanalization on the second follow-up, and 4 aneurysms showed progression of the previously noted recanalization on second follow-up. In the 2 aneurysms that showed new recanalization on the second angiogram, the first follow-up angiogram was within 4 months of the treatment.

Ten aneurysms were retreated: 4 by surgery, 5 by recoiling, and 1 by Neuroform stent placement only. Indications for retreatment were significant recanalization in 9, including 1 with worsening mass effect and intentional staged treatment in 1. One additional patient is waiting recoiling of a significantly recanalized aneurysm. Among these 11 aneurysms, 9 aneurysms including 1 without significant recanalization were treated with >50% Matrix.

Discussion

Our data suggest that the Matrix coil has a satisfactory safety profile as supported by 2 other studies. Clinical follow-up showed no evidence of adverse effects related to the material such as development of delayed thromboembolism, inflammation, or hydrocephalus.

However, the main conclusion drawn from our study is that despite its higher cost, the Matrix coil is not an improvement over the bare platinum coils in preventing aneurysm recanalization. This is based on average 12-month angiographic follow-up of 63.5% of Matrix-treated aneurysms. The overall recanalization rate for Matrix was 40.4%: 18.2% (4/22) for S/S (combined VS/S and S/S), 55.6% for S/W, 67.7% for L, and 100% (1/1) for G group aneurysms. In the group of aneurysms treated with >50% Matrix by length, the overall recanalization rate was 42.9%, 12.5% (2 of 16) for S/S, 50% (4 of 8) for S/W, and 81.8% (9 of 11) for L group aneurysms. These recanalization results are worse than that reported by the UCLA group in their 11-year experience with 53.4% angiographic follow-up (average 11 months). 21% overall recanalization with 5.1% for S/S, 20% for S/W, 35.3% for L, and 59.1% for G aneurysms, respectively. Similarly, Raymond et al reported a 33.6% recanalization rate (different definition) for 381 aneurysms coiled with bare platinum coils at a mean of 12.3-month follow-up. Our clinical findings are consistent with recent animal data. In an elastase-induced experimental aneurysm model on rabbits, Matrix coils resulted in less dense packing (22% versus 33%) and more recanalization (33% versus 22%) compared with bare platinum coils.

### Table 3. Class Changes on Follow-Up

<table>
<thead>
<tr>
<th>Class</th>
<th>Worse</th>
<th>Same</th>
<th>Better</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>4/10</td>
<td>5/13</td>
<td>NA</td>
<td>9/7</td>
</tr>
<tr>
<td>Class 2</td>
<td>9/6</td>
<td>12/9</td>
<td>2/2</td>
<td>23/17</td>
</tr>
<tr>
<td>Class 3</td>
<td>NA</td>
<td>9/6</td>
<td>6/5</td>
<td>15/11</td>
</tr>
<tr>
<td>Total</td>
<td>13/10</td>
<td>26/18</td>
<td>8/7</td>
<td>47/35</td>
</tr>
</tbody>
</table>

Numbers in the parentheses indicate numbers of aneurysms that received >50% Matrix coils by length.

100%) by total length of detached coils within treated aneurysms. Forty-six aneurysms were treated with >50% Matrix coils (average 80%) by length.

### Table 4. Recanalization/Total No. of Aneurysms

<table>
<thead>
<tr>
<th>VS/S</th>
<th>S/S</th>
<th>S/W</th>
<th>L</th>
<th>G</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>1/0/2</td>
<td>1/0/3</td>
<td>2/2/2</td>
<td>2/2/3</td>
<td>0/0</td>
</tr>
<tr>
<td>Class 2</td>
<td>1/0/2</td>
<td>6/4/12</td>
<td>1/1/2</td>
<td>4/3/5</td>
<td>1/1/1</td>
</tr>
<tr>
<td>Class 3</td>
<td>0/0/1</td>
<td>0/0/2</td>
<td>3/2/5</td>
<td>5/4/7</td>
<td>0/0</td>
</tr>
<tr>
<td>Total</td>
<td>2/0/5</td>
<td>7/4/17</td>
<td>6/5/9</td>
<td>11/9/15</td>
<td>1/1/1</td>
</tr>
<tr>
<td>%</td>
<td>40/0</td>
<td>41.22/3.5</td>
<td>66.72/5.6</td>
<td>73.32/6.7</td>
<td>100/100</td>
</tr>
</tbody>
</table>

Numbers in the parentheses indicate numbers of aneurysms developed over 10% recanalization.
The retreatment of the aneurysm due to recanalization was performed in 10 cases (21.3%), of which 8 were treated with >50% Matrix. This is similar to the results of the ACTIVE study in which 21.6% (16/74) of aneurysms were retreated within 1 year.\textsuperscript{14} In contrast, Raymond et al reported a retreatment rate of 7.8% for 383 aneurysms treated with GDCs during an average follow-up period of 31 months.\textsuperscript{6}

Our study has limitations, including retrospective analysis, no internal bare platinum control group, selection bias, and the relatively small number of cases treated with Matrix coils. Nonetheless, our results are based on cases treated with a homogeneous technique in a single center during a relatively short period of time with a relatively high percentage of angiographic follow-up (76.1% of patients with aneurysms treated with >50% Matrix). The average angiographic follow-up time for our series was comparable to that reported for GDC bare platinum coils\textsuperscript{17} (12 months versus 11 months). The bioactive coating of Matrix coil is reportedly absorbed in 3 months.\textsuperscript{8} Most of our recanalized cases were recognized on the first follow-up angiogram within 1 year of treatment, some of which showed progression of recanalization on the second follow-up angiogram. Vinuela et al reported that, in their experience, most aneurysm recanalization with GDCs occurred within 3 months.\textsuperscript{8,4}

The main cause of the poor initial results is most likely the high friction of Matrix coils,\textsuperscript{12} which causes compartmentalization of the coils within the aneurysm, preventing dense packing. In our series, the immediate postembolization complete occlusion rate (class 1) was 17.6%, residual neck (class 2) 40.5%, and aneurysm filling (class 3) 41.9%. The ACTIVE study showed similar results of 15% complete occlusion. One preliminary clinical study reported 5 cases of complete occlusion out of 20 aneurysms treated by using Matrix coils alone.\textsuperscript{11} These occlusion rates are less than previously reported (average 54%) for GDC.\textsuperscript{3,5,6,19}

Another possible cause of the high recanalization rate of Matrix coils demonstrated in our series may be the absorbable nature of the bioactive coating. The bioactive coating of the Matrix coils, which comprises 70% by volume, is absorbed in 3 months.\textsuperscript{8} If complete aneurysm closure does not occur by this time, the amount by volume of platinum within the aneurysm may ultimately only be 10% or less, which may not be enough to prevent recanalization mechanically.\textsuperscript{22} Tamatanii et al reported that the mean embolized coil volume of angiographically stable GDC-treated aneurysm was 30.8±10.2%, and that of recanalized aneurysms was 19.9±10.6% (P=0.03%).\textsuperscript{22}

Only 27.7% (13 of 47) of aneurysms treated with Matrix showed worsening of classification (from class 1 to 2 or 3 or from class 2 to 3), despite 57.4% (27 of 47) of those aneurysms showing some degree of angiographic recanalization. Therefore, recanalization of the aneurysm can occur without change in the class. This point is important in the interpretation of the ACTIVE study by Boston Scientific, in which recanalization was defined as worsening of classification. In the ACTIVE study, 67% of Matrix-treated aneurysms showed sac filling (class 3) immediately after treatment, so that recanalization in this large group of patients was excluded. In addition, retreated cases were excluded in their recanalization assessment. This uncritical interpretation of the ACTIVE data suggested an overall recanalization rate of 15% at 12 months, which is misleading. Therefore, as discussed previously, interventionalists should interpret the purported results of the ACTIVE study with caution.\textsuperscript{23}

**Conclusions**

In our single center experience, Matrix coils had a satisfactory safety profile. However, immediate and midterm follow-up results with Matrix coils were worse than those reported for bare platinum coils. Matrix coils resulted in less dense packing and less complete occlusion of the aneurysm immediately after treatment, which is especially worrisome when treating ruptured aneurysms that may not be well protected from early rebleeding. Midterm angiographic follow-up data showed an unexpectedly high rate of recanalization and a high rate of retreatment. Therefore, we do not recommend the use of Matrix coils for endosaccular coiling of cerebral aneurysms. Our data also emphasize the importance of evaluating all new products in a well-controlled randomized trial.

**References**


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